2.0 Methods, Materials, and Descriptions of Chemical Treatment Pilot Units

This section of the report describes testing and sampling activities conducted at the ENR test cells and planned (but not executed) for the Phase 2 site at the Big Cypress Seminole Indian Reservation (BCSIR). Where additional information is available in the appendices (Volume 2) of this report, a short summary and reference to a particular appendix is provided.

Methods and materials used for laboratory and field tests and evaluations and basic data analysis procedures are described below for the following efforts undertaken as part of the project:

- Laboratory prescreening for chemical selection (fully described in Appendix A)
- Laboratory evaluation of polyaluminum chloride (fully described in Appendix B)
- Field sampling at ENR test cells
- Verification sampling at ENR test cells
- Paired watershed analysis treatment system performance at ENR
- Tracer study at ENR test cells (fully described in Appendix C)
- Preliminary hydraulic evaluation at Phase 2 site

Additionally, the chemical treatment pilot units used at the ENR and the treatment pond designed for use at the BCSIR are described in this section.

2.1 Methods and Materials

2.1.1 Laboratory Prescreening for Chemical Selection

Previous testing work established the suitability of alum and ferric iron salts for precipitation/adsorption of phosphorous to the low ppb range. Previous testing had also established the appropriate pH ranges for carrying out these reactions and minimizing the quantity of residual soluble metal in the treated water. The intent of this prescreening testing was to verify earlier testing results and to determine the starting point conditions for pilot testing. The objectives of the prescreening testing were as follows:

- Verify coagulant dosage/pH relationship versus residual P and residual soluble metal.
- Select the appropriate flocculation polymer(s) and starting dosage(s) for use at the pilot scale.
- Simulate solids contact in the laboratory and observe solids settling characteristics and supernatant quality.
- Simulate sludge storage in the laboratory and observe whether objectionable feedback of P or residual metal occurs over time.

Complete details of the chemical selection process are provided in Appendix A and Appendix B. A brief summary is provided here to provide the reader a sufficient background for the sections on the project results.

Technical Approach

The performance of both PACL (replacing alum used in initial tests) and ferric chloride were evaluated on two source waters:

- Water coming directly from the EAA – what might be expected to enter the STAs now being constructed
- Water already treated through the ENR Project, the pilot STA project

Alum was initially tested, but issues concerning the potential effects of sulfate on mercury cycling resulted in a switch to the testing and use of PACL. Ferric chloride was selected as the iron coagulant to be tested because: 1) previous testing efforts on colored humic acid surface waters have not shown a measurable difference between ferric sulfate and ferric chloride treatments, 2) concerns about potential addition of sulfate ion on mercury cycling were being considered in selected an aluminum coagulant, and 3) use of ferric chloride provided the potential for an analysis of effects from chloride residuals in the treated water stream.

The testing was conducted in a sequential manner to: 1) verify optimum coagulant dose and its effect on pH and residual metals concentrations, 2) select appropriate polymer products and optimize dosage for startup at the pilot scale, 3) simulate the solids contact reaction and observe solids characteristics at the higher solids concentrations and repeated polymer dosing that are expected in the pilot-scale, and 4) simulate solids storage and observe whether measurable feedback of P or residual metal occurs over time.

The schedule of activities is shown in Exhibit 2-1 below.

EXHIBIT 2-1
Research Schedule

Description	Activity Date(s)
Mobilization/Lab Coordination	3/1 - 3/5
Laboratory Safety Training	3/8
Sample Collection	3/8
Coagulant Dose Testing	3/9
Polymer Prescreening	3/10
Polymer Optimization	3/11
Solids Contact Testing	3/12
Solids Storage Evaluation	3/24 – 7/22

2.1.1.2 Standard Testing Procedures

Feedstock Collection. Samples representative of EAA effluent (North EAA) and STA effluent (SSTA) were collected from the feed reservoirs at the North and South ENR test sites. Approximately 35 gallons were required from each site. To ensure fresh samples, aliquots were collected on Monday for tests conducted Tuesday and Wednesday; fresh aliquots were collected on Wednesday for use in the tests conducted Thursday and Friday. Approximately 25 gallons were collected from each site at each sampling event. The samples drawn from the north ENR site were referred to as NEAA. The samples drawn from the South ENR site

were referred to as SSTA. Samples not needed immediately were stored in a walk-in cooler. All samples were handled in the manner and within the time frames prescribed in the Quality Assurance Project Plan (QAPP).

An initial influent composite of each of the NEAA and SSTA waters was analyzed for pH, TP, total dissolved phosphorous (TDP), dissolved orthophosphate, alkalinity, dissolved organic carbon (DOC), turbidity, color, dissolved iron and aluminum, and total suspended solids (TSS).

General Jar Testing Procedure. Testing was carried out using procedures described by Hudson and Wagner (1981) for conventional jar testing. The procedure described in Appendix A was used to conduct solids contact testing in the jar test apparatus. Prior to jar testing, the raw water samples were titrated with the coagulants and acid to determine alkalinity and the acid/base requirements for each specific jar. Commercial grade reagents (coagulants, acid/base, polymers) were used throughout the testing.

Approximately 28 jar tests were conducted:

(2 sources) x (2 coagulants) x (6 coagulant doses) x (1 polymer dose) = 24 jars
+ 10 % replication = 4 jars
Total = 28 jars

Samples for dissolved P analysis were approximately:

28 experiment + 3 duplicate + 3 spike + 3 blanks = 37

Solids Contact Simulations. A solids contact simulation was performed with the alum and ferric chloride coagulant dosage and the optimized polymer and dosage determined from the previous testing. This set of tests allowed a qualitative assessment of the solids characteristics, as well as an opportunity to verify residual P and metal concentrations after treatment.

Solids contact was simulated by running sequential jar tests while retaining the sludge produced from previous tests. The estimated hydraulic retention time of liquid in the pilot reactors was expected to be approximately 2 hours. Assuming a minimum target solids retention time of 1 day, the number of batches needed to fully simulate pilot operating conditions was calculated as the solids retention time/hydraulic resident time (SRT/HRT) = 24/2 = 12 batches.

There were four solids contact tests: 2 source waters * 2 coagulants = 4.

Samples for turbidity/settling velocity analysis were approximately:

4 tests * 3 batches each * 4 time intervals + 5 duplicate = 53 samples

Samples drawn for the full set of analytical testing on raw samples and on the final batch were approximately:

2 raw + 4 final + 1 spike + 1 duplicate +1 blank = 9 samples

Sludge Storage Evaluation. A sufficient quantity of sludge solids was generated using both alum and ferric chloride to conduct a solids storage evaluation. The intent of this evaluation was to discern whether the solids generated are prone to digestion and flotation over time, and whether there is the potential for significant feedback of P or metal from the solid to the liquid phase.

Generation of Sludge Solids. The south solids contact system located at the South Supplemental Technologies site at the ENR project site was used to generate sludge solids for the testing. This facility consists of three 200-gallon rapid mix/floc tanks in series followed by a parallel plate separator. The mix/floc tanks are equipped with variable speed mixers to allow user control of mixing intensity. The first tank in the series was used as a rapid mix tank. The following two tanks were used to provide tapered flocculation prior to solids settling. Sludge recirculation was provided from the bottom of the separator to the second mix tank (first floc tank) using a centrifugal pump.

Influent consisted of low-P STA effluent waters. Influent flow rate was generally controlled to between 10 and 12 gpm. Chemical doses approximated those optimized in the testing described previously.

Alum sludge was produced on Wednesday, March 24. Approximately 3,500 gallons of influent were treated in the system, from which approximately 11 gallons of dilute sludge were recovered from the bottom of the solids separator. Iron sludge was produced on Thursday, March 25. Approximately 2,900 gallons of influent were treated in the system, from which approximately 10 gallons of dilute sludge were recovered from the bottom of the solids separator.

Sludge Storage Testing. Approximately 4 gallons of thickened alum sludge was transferred to a 10 gallon aquarium and covered with approximately 6 gallons of treated effluent. For the iron test, the 10 gallon aquarium was completely filled with a dilute iron sludge mixture. After 24 hours quiescent settling, the alum storage reactor had a settled sludge volume of approximately 2 gallons, and the iron storage reactor had a settled sludge volume of approximately 3 gallons.

The reactors were stored in the MWTS/PSTA project trailer at the South Supplemental Technologies test site. Reactors were kept at room temperature, away from direct sunlight. Reactor volume lost to evaporation was replaced using distilled water. The sludge from each reactor was sampled monthly and analyzed for TP and total suspended solids (TSS). The water column was sampled concurrently and analyzed for TP, TDP, and dissolved metal (Al or Fe), and monitored for pH and temperature. The supernatant was sampled every 2 weeks and analyzed for dissolved total P. After the reactors were sampled (every 2 weeks), the contents were thoroughly mixed by hand and allowed to resettle.

2.1.1.3 Analytical Support and Data Management

Analytical methods were as described in the project QAPP. The District provided 1-day turn around on TP and TDP samples for approximately 30 samples per day for 3 days. This was sufficient to allow appropriate decision-making choices in the first days to complete polymer dosage optimization. Measurement of pH, alkalinity, and turbidity were conducted by the testing staff onsite. All other parameters and all phosphorous determinations in excess of 30 samples per day for 3 days of testing were analyzed by PPB Environmental Laboratories (PPB). PPB provided rapid turn around of sample results for the prescreening testing effort to aid in decision-making. Samples were shipped overnight to PPB via Fed Ex in order to receive faxed or verbal results by the evening of the next business day.

2.1.3 Field Sampling at ENR Test Cells

The SAC's recommended changes to the Phase 1 research plan, as outlined in Section 1, changed the experimental design for the ENR testing. This section incorporates the

recommended change to a paired watershed design using fewer experimental variables, but with a longer period of testing.

The ENR MWTS sampling program focused on the following components:

- Evaluating effects of ferric chloride and PACL coagulants
- Tracking the water and TP budgets through the serial treatment system
- Quantifying rate and fate of residual solids generated by chemical additions
- Quantifying solids overflow from chemical unit into wetland, solids deposition within wetland, and solids export from the wetland
- Assessing the chemical (ionic conditioning) signature of the water flowing through the wetland component of the MWTS and the nature and efficiency of the ionic conditioning effect provided by the wetland

2.1.3.1 Startup of MWTS Project Operation

Startup testing included wetland tracer tests using lithium chloride to evaluate the hydraulic flow patterns and measure hydraulic residence time. Tracer (slightly more than 1 liter) was added to the inlet of each ENR test cell. Samples were collected once daily over a period of 10 days at the outflow. In addition, each cell was sampled at internal stations, three stations arrayed across the width of the cell at both the one-third and two-third distances along the flow path.

Phase 1 experimentation in the ENR test cells consisted of several treatments for P-loading and removal, but a single depth and a single target HLR. Three test periods were conducted, a 7-month baseline calibration period, an experimental testing period of greater than nine months (cell-dependent), and a 5-week verification testing period.

2.1.3.2 Operation of the ENR MWTS

The wetland cell target operating depth was 30 cm, and the target HLR was 10 cm/d. Chemical parameters included in the ENR operational sampling are summarized in Exhibit 2-2.

EXHIBIT 2-2
Sampling Parameters for the ENR MWTS

Selected Nutrients	Dissolved Metals	Metered and Miscellaneous Parameters
Total phosphorous	Iron	Dissolved oxygen
Total dissolved P	Aluminum	Temperature
Dissolved orthophosphate	Calcium	pH
Total Kjeldahl nitrogen	Sodium	Specific conductance
Ammonia nitrogen	Magnesium	Total suspended solids
Nitrate	Potassium	Total dissolved solids
Silica	Manganese	Alkalinity
Sulfate		Color
Nitrite		Turbidity
Total organic carbon		Hardness (calculated)
Chloride		

All field and laboratory analyses were performed by field personnel operating under the project's comprehensive QAPP.

The within-wetland water-quality sampling was done from boardwalks to the extent possible to limit the disturbance of the vegetative and soil structure in the test cells. Two boardwalks were constructed in each of the ENR test cells. Boardwalks provided perpendicular access at the one-third and two-third intervals along the flow path. This alignment allowed incremental sampling along a longitudinal gradient of the ENR cell. Exhibit 2-3 illustrates the boardwalk placement and sampling locations.

The ENR test cells were sampled quantitatively for multiple water quality parameters. Exhibit 2-4 summarizes the sampling program, which includes weekly, biweekly, monthly, and quarterly sampling routines. Samples of the test cell source water were routinely collected and analyzed once every week from the ENR inflow distribution pipe by the District. Therefore, CH2M HILL did not conduct routine monitoring of the ENR source water with the exception of color and turbidity.

CH2M HILL sampled the monthly parameters for each test cell at three locations

1. The inflow to the wetland cell (which became the plant outflow in the treatment cells during the treatment period)
2. The one-third point of the wetland
3. The outflow from the wetland

Temperature, pH, conductivity, and dissolved oxygen were monitored through direct measurements 2 days per week.

Grab samples were collected from four wetland sampling locations (wetland inflow, one-third and two-third points along flowpath, and outflow) from each of the six test cells and analyzed for the three forms of phosphorous (TP, dissolved P, and soluble reactive P [SRP]) on a biweekly basis. The biweekly sampling frequency presumed that the nominal hydraulic residence time of each subcell was greater than a week but less than 2 weeks.

On a monthly basis, the grab samples from three sampling locations in each test cell (wetland inflow, one-third distance, two-thirds distance, and outflow) were analyzed for additional water quality constituents. The analytes that were monitored monthly are identified in Exhibit 2-4.

Sediment samples were obtained quarterly at two wetland locations, the one-third and two-third longitudinal flow path points within each test cell. Samples consisted of cores (approximately 2.5 cm diameter). Multiple cores were pulled at each of the two locations. Samples were analyzed for P fractions and iron and aluminum as listed in Exhibit 2-4.

2.1.4 Verification Testing Program

The vegetative community within each test cell was characterized three times over the course of testing at the ENR: July 1999, October 2000, and April 2001. Additional data was obtained from surveys performed prior to July 1999 by District staff (SFWMD, 2000). CH2M HILL scientists estimated percent cover for the major taxa in twelve subareas within each test cell. The twelve subareas were delineated by first dividing the cell into thirds using the boardwalk locations, then each third was further subdivided into four equal areas. Each subarea was approximately 10 m by 10 m. Visual estimates of plant cover by species within each subarea was then recorded. Subarea cover estimates were averaged to provide the cover estimate for the test cell.

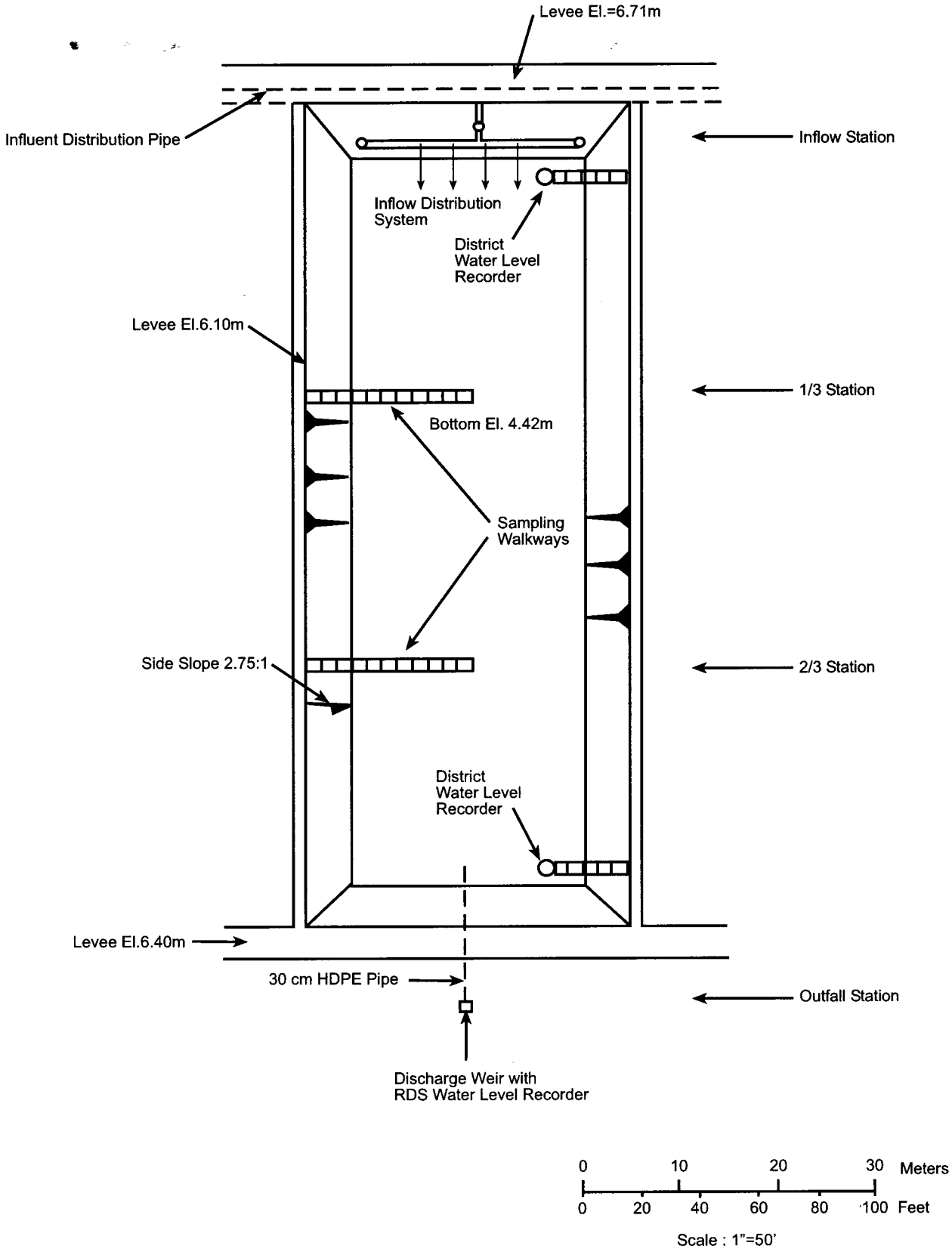


Exhibit 2-3. Plan View of Typical MWTS Test Cell Showing Sampling Locations

EXHIBIT 2-4
Operational Sampling Plan for ENR MWTS
Final Report

		Two Days per Week				Biweekly						Monthly					Quarterly				
		MWTS	Wetland			MWTS	Wetland					MWTS	Wetland				Wetland				
Parameter	Analytical Method	Inflow	Inflow	1/3 Point	2/3 Point	Outflow	Inflow	Inflow	1/3 Point	2/3 Point	Outflow	Inflow	Inflow	1/3 Point	2/3 Point	Outflow	1/3 Point	2/3 Point			
Field Sampling																					
Flow		C	C			C															
Water Temperature	EPA 170.1	X	X	X	X	X															
Dissolved Oxygen	EPA 360.1	X	X	X	X	X															
pH	EPA 150.1	X	X	X	X	X															
Conductivity	EPA 120.1	X	X	X	X	X															
Water Quality Analyses																					
Phosphorous (P) Series																					
Total P	EPA 365.3						D	X	X	X	X	D	X	X		X					
Dissolved P	EPA 365.3						D	X	X	X	X	D	X	X		X					
Soluble Reactive P	EPA 365.3						D	X	X	X	X	D	X	X		X					
Nitrogen (N) Series																					
Total N	Calculation											D	X	X		X					
Ammonia N	EPA 350.1											D	X	X		X					
Total Kjeldahl N	EPA 351.2											D	X	X		X					
Nitrate+Nitrite N	EPA 353.2											D	X	X		X					
Total Organic Carbon	EPA 415.1											D	X	X		X					
Sediment Analysis																					
Phosphorous (P) Series																					
Total P	EPA 365.3																X	X			
Dissolved P	EPA 365.3																X	X			
Soluble Reactive P	EPA 365.3																X	X			
Iron	SW-846 6010																X	X			
Aluminum	SW-846 6010																X	X	72	7	79
Supplemental Parameters																					
Total Dissolved Solids	EPA 160.1											D	X	X	X	X			432	43	475
Total Suspended Solids	EPA 160.2											D	X	X	X	X			432	43	475
Color	EPA 110.2											X	X	X	X	X			540	54	594
Chloride	EPA 325.2											D	X	X	X	X			432	43	475
Sulfate	EPA 375.4											D	X	X	X	X			432	43	475
Alkalinity	EPA 310.1											D	X	X	X	X			432	43	475
Hardness (Calculated)	EPA 130.2											D	X	X	X	X			0	0	0
Aluminum	SW-846 6010											D	X	X	X	X			432	43	475
Magnesium	SW-846 6010											D	X	X	X	X			432	43	475
Calcium	SW-846 6010											D	X	X	X	X			432	43	475
Iron	SW-846 6010											D	X	X	X	X			432	43	475
Silica	EPA 370.1											D	X	X	X	X			432	43	475
Turbidity	EPA 180.1											X	X	X	X	X			540	54	594

Notes:
C Continuous depth monitoring
D District data were used

Florida Department of Environmental Protection (FDEP) Phase 1 Testing Protocol/Process Verification sampling covered a time period of five weeks beginning in late November 2000 and ending December 27, 2000. Testing followed the sampling regime, analysis, and protocols as described in the contract for the project. The duration of the verification testing was modified from a 12 week period with six sampling events to a five week period with five sampling events. Water quality sampling stations included the raw water inflow, pilot plant outflow, and three stations within the wetland test cells (one-third, two-thirds, and outflow).

Final verification testing followed the FDEP guidance document, *Phase 1 Procedures for Evaluating Potential for Effects to Everglades Biota from Discharges from Pilot Testing of Supplemental Technologies*. The FDEP Phase 1 Testing Protocol/Process Verification consisted of the following three elements:

- Water quality verification testing
- Toxicity testing
- Algal growth potential (AGP) assay

All toxicity and AGP tests were completed following screening level procedures using undiluted composite samples.

2.1.4.1 Physico-Chemical Verification Testing (5 weeks)

CH2M HILL conducted a 5-week verification-sampling program at the ENR test cells. The experimental design for the FDEP verification testing followed the same general experimental design utilized for the 15-month ENR test period conducted for the operational sampling at the ENR.

The residual solid/liquid sidestream from the chemical treatment units at both the North and South ENR test sites was tested five times during the verification period for TP, SRP, TDP, TKN, nitrate, nitrite, ammonia, total suspended solids, total organic carbon, alkalinity, total dissolved solids, sulfate, reactive silica, chloride, and dissolved metals (aluminum, iron, calcium, magnesium, potassium, and sodium). In addition, during the verification testing a Toxicity Characteristic Leaching Procedure (TCLP) analysis was run once on the sidestream from the pilot treatment units at the North and South ENR MWTS test sites.

2.1.4.2 Toxicity Testing

The FDEP testing protocol requires toxicity testing on the outflow water from each experimental watershed. Therefore, outflow waters from each of the five wetland cells used (NTC-FeCl, NTC-Control, NTC-PACL, STC-Control, and STC-PACL) were tested once during the 5-week verification test. The outflow samples were tested for chronic toxicity in a laboratory, and the following three test species were used for toxicity screening:

- *Cyprinella leedsi* (bannerfin shiner) — EPA/600/4-91/002 Method 1000.0
- *Ceriodaphniua dubia* (water flea) — EPA/600/4-91/002 Method 1002.0
- *Selanastrum capricornutum* (green alga) — EPA/600/4-91/002 Method 1003.0

Screening level toxicity testing were performed on five composite samples of the outflow water, three from the northern cells, and two from the southern cells. For both test cell sets, a composite sample for each chemical treatment and control were collected.

2.1.4.3 AGP Assay

AGP assays were used to confirm that the MWTS technology is effective in reducing the bioavailable nutrient concentrations of the MWTS overflow. A single set of AGP assays on the outflow waters (iron salt, aluminum salt, and control) at the three northern and two southern test cells were performed concurrently with toxicity testing. The assays were performed in accordance with EPA Method 600/9-78-018. Screening level AGP testing were performed on five composite samples, three from the northern test cells, and two from the southern test cells. For both test cell sets a composite sample for each chemical treatment (i.e., iron salt, aluminum salt, and control) were collected.

2.1.5 Paired Watershed Analysis

The experimental design for the ENR testing is described in the MWTS Research Plan (CH2M HILL, 1999). Two study sites, the NTCs and STCs, each contained three treatment cells. Within the NTC, two cells were used for treatment and one as the control. At the STC site one cell was used for treatment and one for control. During the baseline calibration period a full suite of nitrogen and phosphorous water quality parameters were measured in each cell, as well as physical parameters. The calibration period was considered adequate when significant relationships between the paired watersheds have been determined for all parameters of interest, as stated above.

This calibration analysis determined whether significant relationships between cells within each site for total phosphorous could be documented using the calibration data available. Six months in the period of record were available for the analysis. This constraint, along with missing values caused by technical problems, left 9 to 10 records available for the analysis of the NTCs, and 13 to 15 records available for the STCs from MWTS sampling.

Prior to startup of the ENR testing conducted by CH2M HILL, the District collected water quality data. The first data records from this period were collected in September 1998. Since the test cells were operated under a different hydraulic regime (depth and HLR) during this time period, and these data were collected by different field crews and analyzed by a different laboratory, the data may differ from the data collected by CH2M HILL. In addition, this sampling covered the period of vegetative community establishment. For these reasons, calibration analysis was done in a stepwise manner, first using the data collected in July through December 1999. Next, the analysis was rerun using the expanded data set that includes the pre-MWTS data collected by the District.

The calibration equation is a mathematical representation of the relation between the treatment watershed and the control watershed. It is developed through empirical methods, such as univariate or multiple linear regression analysis. If the relation is clear and strong, univariate, linear regression equation may be sufficient. If there is much noise in the data, it is necessary to use more complex methods, such as robust regression and covariate independent variables. This analysis was done in steps from the simplest to the more complex analysis.

The first regressions were standard univariate ordinary least squares (OLS) regression using a single independent variable, the nutrient concentration in outflow from the control cell. Multiple regression techniques may use covariates such as water depth or hydraulic loading. The robust regression techniques utilized methods developed by Rousseeuw and

Yohai (1984) and others. These robust methods keep the outliers intact in the data set but minimize their influence as well as minimizing bias in the estimates of the slope coefficients caused by non-Gaussian distributions in the error terms, by adjusting the formulas used to calculate the slope coefficients. The procedure also iteratively recalculates the slope coefficient using the adjusted formulas to minimize influence of the outliers and non-Gaussian distribution bias.

Treatment period regressions, using OLS and Robust Regression techniques were developed after the completion of the sampling at the end of December 2000. The calibration and treatment period regressions were then compared to quantify differences between the calibration and treatment periods for each treatment cell.

2.1.7 Tracer Study

Tracer studies were conducted at the NTCs and STCs for the MWTS project to characterize the hydraulic performance of the experimental wetland cells. Tracer studies yield important information such as the actual HRT, volumetric efficiency, number of tanks in series, and dispersion number. These parameters are used to refine predictive models used to estimate the phosphorous removal capacity of a given MWTS treatment. Tracer studies were conducted at cells NTC-FeCl, NTC-Control, and NTC-PACL at the North site; and cells STC-5, STC-Control, and STC-PACL at the South site.

2.1.7.1 Materials and Methods

Based upon prior success using lithium chloride as a tracer solution for the PSTA project, a 40 percent (by volume) lithium chloride solution was selected as the appropriate tracer for the MWTS experiments. Background lithium samples were collected at the inflow and outflow from each cell on two consecutive days prior to the start of each experiment. Exhibit 2-5 presents a summary of the background lithium concentrations for the test cells.

EXHIBIT 2-5
Summary of Background Lithium Concentrations at the MWTS Test Cells

Site	Location	Concentration (µg/L)		Mean
		1/18/00	1/19/00	
NTC-2	Inlet	25.2	24.8	25.8
	Outlet	26.8	26.4	
NTC-3	Inlet	26.3	24.8	26.6
	Outlet	27.4	27.7	
NTC-4	Inlet	28.0	25.0	27.1
	Outlet	27.8	27.4	
STC-5	Inlet	29.8	32.5	31.5
	Outlet	32.0	31.6	
STC-6	Inlet	30.8	33.9	35.1
	Outlet	35.1	40.6	
STC-7	Inlet	31.5	32.5	32.1
	Outlet	31.4	33.0	

The test cells used for the MWTS project operated with a nominal HLR of 10 to 11 cm/d and depths ranging from about 28 to 45 cm. Each test cell had a nominal surface area (at grade) of about 2,240 m^2. For these combinations of operating depth, surface area, and HLR, the volume of any test cell ranged from about 646 to 1,078 m^3, with nominal HRT ranging from 2.4 to 4.0 days.

2.1.7.2 Tracer Application

Tracer dosages were calculated using the background concentration and cell volume data shown in Exhibit 2-5 and Exhibit 4-5. The actual volume of tracer solution was calculated as follows:

$$\text{Dosage} = \frac{\text{background concentration (mg/L) x cell volume (L) x 10 (peaking factor)}}{\text{lithium ion concentration in brine solution (mg/L)}}$$

A peaking factor of 10 was used to ensure sufficient resolution between background levels and the targeted peak concentration observed during the studies.

The calculated dosage of tracer solution for each cell (approximately 1 liter) was measured into a clean glass bottle and mixed with source water (approximately 50:50) to reduce the density differential between the solution and the water in the cells. The dosages are summarized in Appendix C.

At the designated starting time for each cell, the inlet pipe was removed at the orifice plate, the solution was poured directly into the inlet pipe, and the pipe was then replaced to flush the tracer into the inlet manifold system.

Sample Collection. Automatic sampling devices (ISCO Model 3700) were installed at the outlet from each cell. The intake screen was positioned to draw samples from the outlet weir boxes. The samplers were programmed to collect 120 mL samples every 4 hours beginning at the time of tracer application. At the completion of each program cycle (24 bottles), field staff replaced the filled containers with clean bottles and re-started the programs to collect the next series of samples. The sample collection frequency was reduced to an 8-hour interval approximately 13 days into the experiments.

Grab samples were collected weekly from the receiving stream to demonstrate that elevated lithium concentrations were not detectable in water flowing into Everglades National Park.

Flow Measurement. Outflow rates were calculated based on inflow measurements, rainfall, and evapotranspiration data collected by CH2M HILL and the District. Outflow rates were estimated coincident with each sample collected by the automatic samplers.

2.2 Description of Chemical Treatment Pilot Units

2.2.1 Pilot Treatment Units at ENR Test Cells

The design of the chemical treatment units for the Phase 1 testing at the ENR was completed in the fourth quarter of 1999. Final modifications to the design were completed after a vendor was selected. Pilot plants were ordered in late October for delivery in early January 2000.

2.2.1.1 Description of Pilot Plants

There are three pilot plants – two at the NTC site and one at the STC site. At the NTC site, one plant is an iron plant and pretreats water directed to NTC-FeCl. The other plant is an aluminum plant and pretreats water to NTC-PACL. NTC-Control at the north ENR is the control cell and receives water (from the pilot plant splitter box) that has not been chemically treated. The single pilot plant at the STC site can be directed to flow to either STC-5 or STC-PACL. STC-Control at the STC site will be the control cell. Photos of the pilot plants are located at the end of this section.

Inflow to the pilot plants flows from a three way splitter box as depicted in Exhibit 2-6. The splitter box consists of a large metal box into which the source water flows. It passes from there into a stilling area, which had as one wall three v-notch weirs associated with three separate outflow basins with separate pipes going to one of three wetland systems. The weirs, when adjusted to equal elevations, caused an equal amount of water to flow over into each of three pipes (see photograph at the end of this section). The pipe from each effluent basin on the splitter box flows to a different system; the iron coagulant system, aluminum coagulant system or a control cell. The target raw water flow rate of 20 to 50 gallons per minute (gpm) to each pilot plant/wetland cell is achieved by using a 10° V-Notch weir with a design head of up to 12-inches. The V-notch weirs were adjustable to equalize flow to the three systems. Water in excess of the target flow rate to each cell that entered the stilling area passed over an 18-inch sharp crested rectangular weir water in another face of the stilling area and was diverted to an overflow basin. The overflow basin drained to the perimeter borrow ditch on the outside of the ENR cells.

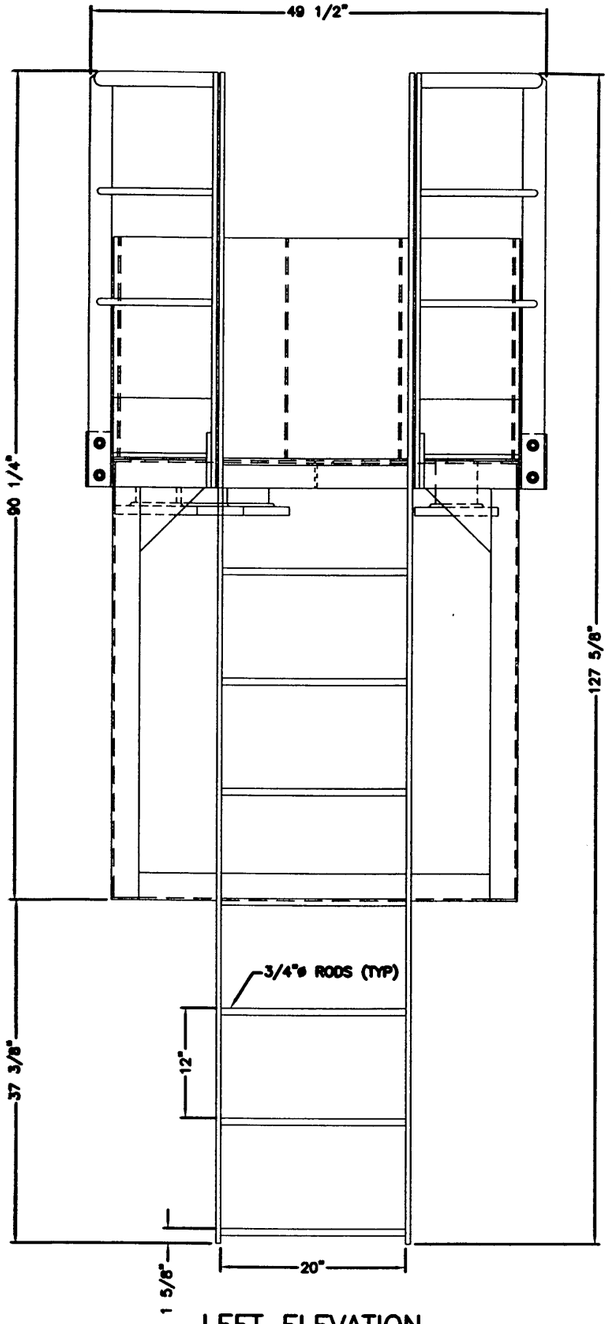
The pilot plants included two duplex 120V outlets with 20 amp ground fault indicators (GFIs) for sampling equipment and lights. Controls for the mixers and pumps were localized at a control panel. Mechanical wetted parts such as mixer shafts and impellers are fabricated of 316 stainless steel. Process tank components were made of carbon steel with a high performance coating system. The pilot facility was designed to operate under gravity flow from the splitter structure through the sludge storage tanks and into the test cells under all conditions.

2.2.1.2 Pilot Plant System

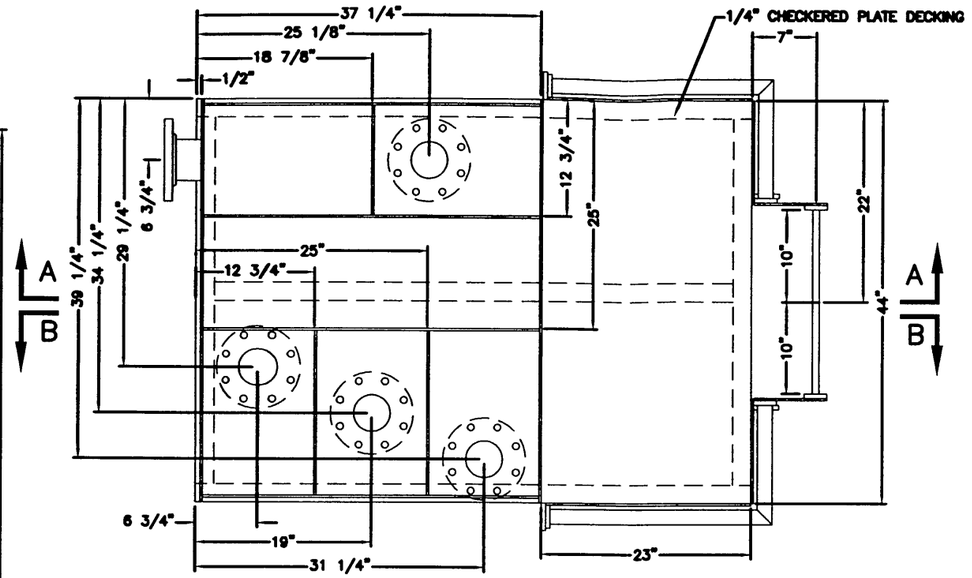
The remaining description pertains to a typical pilot plant system. A process flow diagram is shown in Exhibit 2-7. A typical plan and profile of the systems is shown in Exhibit 2-8.

From the splitter box the influent flowed into the first of two rapid mix tanks. Both rapid mix tanks had volumes of approximately 20 gallons and were fitted with fixed speed mechanical mixers with axial flow type rapid mix impellers. These tanks were rectangular which discouraged rotation of the liquid contents. Coagulant were introduced to the first rapid mix tank and polymer was added to the second.

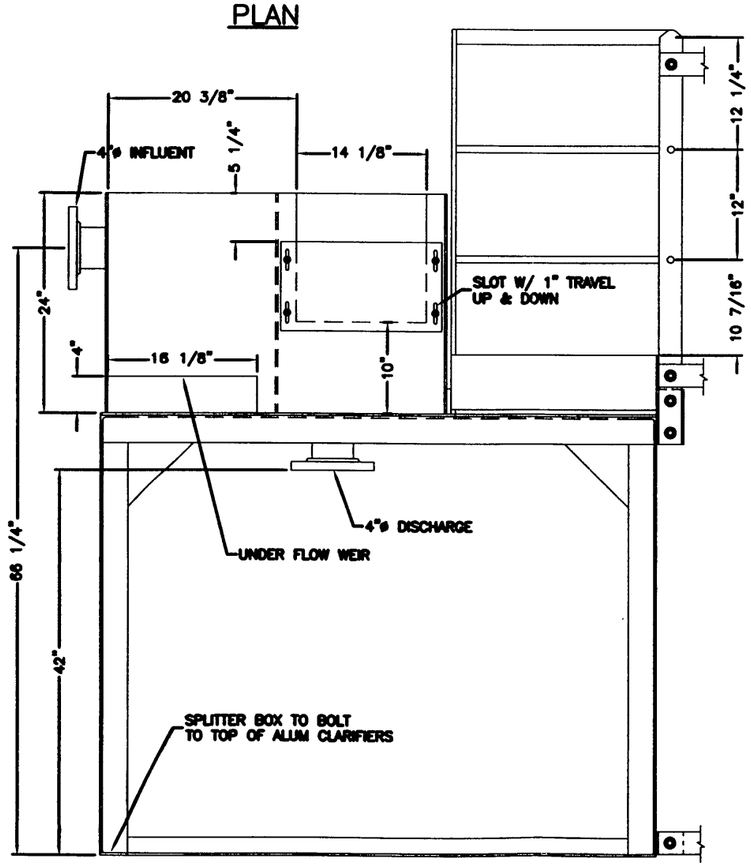
The coagulant feed system consisted of a diaphragm metering pump (0 to 2 gallons per hour [gph]) with manual stroke length and speed/frequency adjustment. Coagulant is fed neat from 55-gallon drums. The polymer feed system consisted of a diaphragm metering pump (0 to 3 gph) with manual stroke length and speed/frequency adjustment, and a polymer makeup system consisting of a 50-gallon polyethylene tank with integral mechanical mixer. Approximately 50 gallons of 0.5 percent solution were made up every other day from neat emulsion. Each metering pump included a 500-mL calibration chamber.



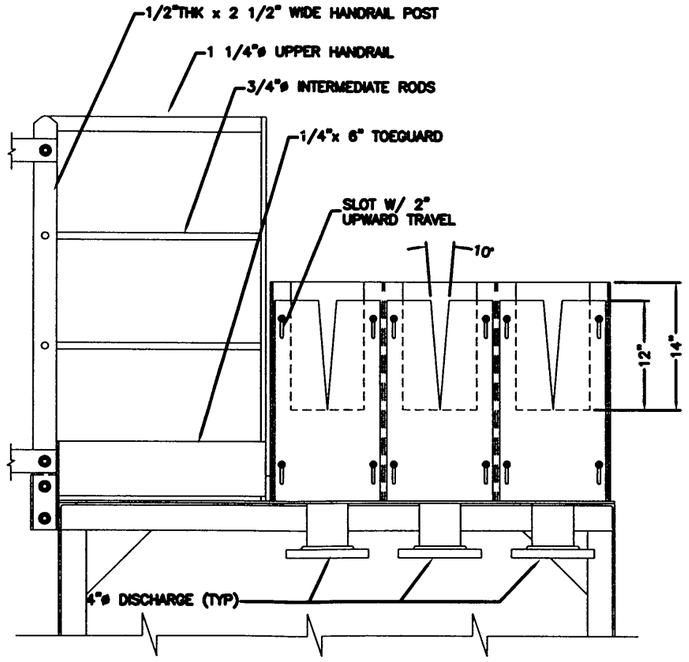
LEFT ELEVATION



PLAN



SECTION A–A



SECTION B–B

SHIPPING WT = 1350 LBS
OPERATING WT = 2660 LBS

Rev.	By	Date
Drawn By	DA	Date 11/11/99
Project Engr.		Approval Date
Job No. CH2-01		Code No. 096

Proprietary Information

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Description

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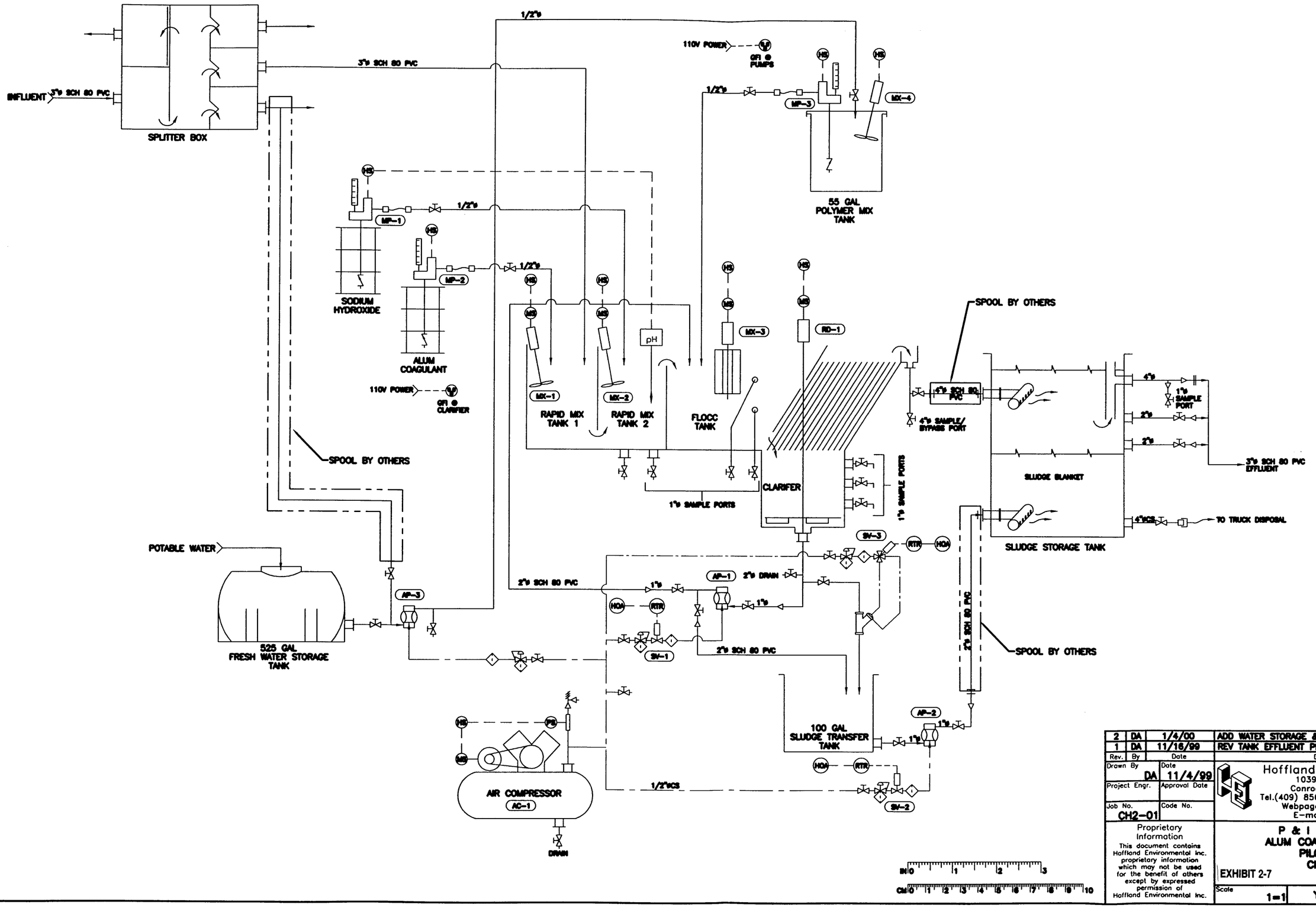
SPLITTER BOX FOR ALUM COAGULANT SYSTEMS (2 REQ'D) CH2MHILL

EXHIBIT 2-6

Scale		Sheet	Rev
1 1/2"=12"	Y-067-TK-01	1	0



Rev.	By	Date	Description
2	DA	1/4/00	ADD WATER STORAGE & AP-3 PUMP
1	DA	11/16/99	REV TANK EFFLUENT PIPE FROM 3"ø TO 4"ø

Drawn By: DA | Date: 11/4/99
Project Engr. | Approval Date
Job No.: CH2-01 | Code No.

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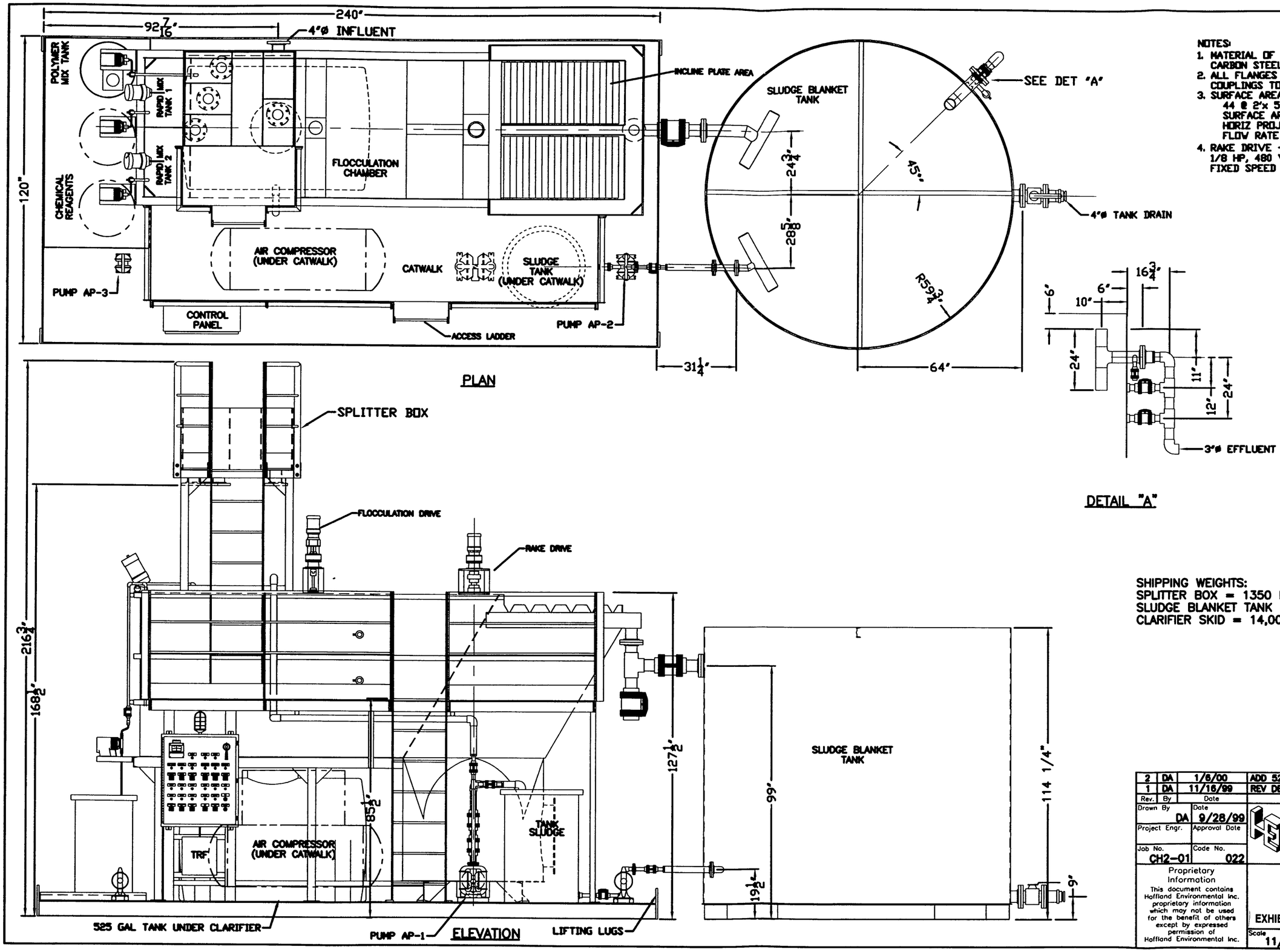
P & I DIAGRAM FOR ALUM COAGULANT SYSTEM PILOT PLANT CH2MHILL

EXHIBIT 2-7

Scale: 1=1 | Y-067-PI-01 | Sheet: 1 | Rev: 2



NOTES:
1. MATERIAL OF CONSTRUCTION TO BE ASTM A-36 CARBON STEEL 1/4" THICK PLATE
2. ALL FLANGES TO BE 150 LB RAISED FACED AND ALL COUPLINGS TO BE FNPT
3. SURFACE AREA SPEC'S:
   44 @ 2'x 3' FRP PLATES
   SURFACE AREA = 440 SQ FT
   HORIZ PROJECTED AREA = 220 SQ FT
   FLOW RATE = 55 GPM
4. RAKE DRIVE - 52"ø RAKE W/ 1/8 HP, 480 VAC, 3 PHASE TEFC MOTOR AND FIXED SPEED GEAR DRIVE

SHIPPING WEIGHTS:
SPLITTER BOX = 1350 LBS
SLUDGE BLANKET TANK = 5,000 LBS
CLARIFIER SKID = 14,000 LBS

Rev.	By	Date	Description
2	DA	1/6/00	ADD 525 GAL TANK AND 1/2" PUMP
1	DA	11/16/99	REV DET "A" PIPE FROM 3"ø TO 4"ø

Drawn By: DA — Date: 9/28/99
Project Engr. — Approval Date
Job No.: CH2-01 — Code No.: 022

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ALUM EQUIPMENT ARRANGEMENT (2 REQ'D)

CH2M HILL

EXHIBIT 2-8

Scale: 11/16=12 | Y-067-FL-01 | Sheet: 1 | Rev: 2

Fifty percent NaOH solution was injected into the iron coagulant system immediately upstream of the coagulant injection point in rapid mix tank one (no pH adjustment was required for the blank cell or the aluminum system). The pH control system consisted of the pH analyzer element, indicator/transmitter, pH controller, and 0 to 2 gph electric diaphragm metering pump with variable stroke and speed controlled by the controller to achieve the target pH setpoint.

From the rapid mix tanks the flow continued into the flocculation tank. The floc tank also received recirculated sludge flow from the plate settler. The floc tank had a volume of 1,500 gallons and was mixed using a variable speed geared mixer with a fence-type flocculating impeller providing a G value ranging from <30 to >70 s^{-1}. The tank was rectangular which prevents the bulk liquid from turning as a unit.

From the floc tank, the chemically treated water passed to the plate settler. The plate settler had a projected horizontal plate area/effective surface area of 220 square feet. The plate settler was equipped with V-notch weirs to ensure equal distribution through the plates.

The underflow line from the plate settler was split into separate recycle and waste sludge lines, with each line having a manual ball valve to select the direction of flow. Typically, flow was directed back to the floc tank. Operations staff manually opened the waste sludge valve periodically (and closed the recirculation valve) in order to waste a predetermined volume of sludge into the 100-gallon, calibrated waste sludge measuring tank.

Recirculated sludge flow was controllable through a timer to as much as 30 gpm continuously. The recirculation pumps were set to pump at approximately 8 gpm, and were on for 30 seconds and off for 90 seconds. Thus, 8 gallons were pumped every 2 minutes, or approximately 4-gpm equivalent continuous flow. This flow rate was increased gradually to maintain a low sludge blanket depth in the plate settler (keep solids in the floc zone).

Both the effluent from the plate settler, and wasted sludge, were directed to the 5,000-gallon sludge storage tank. Wasted sludge was transferred from the waste sludge measuring tank into a diffuser in the bottom of the sludge storage tank using a solids transfer pump with local on/off control having a flow rate of up to 20 gpm. The intent was to accurately measure the amount of sludge wasted using the calibrated waste sludge measuring tank, and then transfer this sludge to the storage tank without causing the storage tank to be stirred up.

Clarified effluent flowed by gravity to the same sludge storage tank and was diffused through a header at the top of the tank so as not to disturb the sludge blanket beneath it. The intention was that sludge be allowed to accumulate in this tank, with clarified liquid flowing over the top of the sludge. There was a scum baffle to prevent floating scum from exiting with the outflow liquid from this tank. Outflow from pilot units flowed by gravity to their respective cells. The sludge storage tanks were fitted with 6-inch quick disconnect fittings to accommodate transfer of sludge to a hauling truck through a flexible hose.

2.2.2 Description of the Cypress Demonstration Pilot

The goal of the Phase 2 project was to reduce phosphorous concentration in wetlands water to acceptable levels in a physical setting similar to a fully operational system. Phosphorous reduction was intended to occur by chemical precipitation/flocculation within a supply pipe, followed by removal of the floc by sedimentation in a pond. The pond outflow would

then enter a wetland treatment system where ionic conditioning could occur. A detailed description of the project and schematic drawings are provided in Appendix D.

The Seminole Tribe, on whose lands the project was to be constructed, decided prior to construction of the system that they did not want to continue to be cooperators for the effort. The District, with the concurrence of the SAC, decided not to develop this second project phase. However, prior to that decision, a hydraulic test was conducted (described below).

A one-time hydraulic integrity, pump test was conducted at the Phase 2 wetland site in order to verify that the wetland could maintain standing water with a pumped inflow. The wetland is hydrologically isolated from the normal surface inflow by a perimeter berm. There was a concern that the hydrologic alternations could increase the percolation rate of soils and underlying strata, such that the wetland would not readily maintain standing water. There is evidence from other wetland systems in the state that water table drawdown can change the character of soils and underlying strata.

The pump test commenced on the morning of September 20, 1999. A portable diesel powered pump was installed between the edge of the wetland and the irrigation canal. Pumping began at 10:00 am. The pump ran nearly continuously for approximately 46 hours. The pump failed at some time early in the morning of the second day, but was repaired and restarted by 11 a.m. The nominal pumping rate was 1,000 gallons per minute (3.8 m^3/min), or 1.44 mgd (5,450 m^3). Allowing for pump downtime the total pumped inflow is estimated as 2.5 million gallons (9,500 m^3).

Prior to the start of pumping, water levels were 60 to 70 cm below the soil surface. After 16 to 18 hours of pumping approximately 7.5 cm of standing water was present over most of the wetland and water was flowing out into the main body of the wetland. Temporary staff gages and piezometers were installed at 10 stations to monitor water level.

Pumping ended at 8:00 am of the third day.

Plants at the North Site

Inflow Splitter Box (above)
Pilot Plants Viewed from Wetland (below)

Iron Plant

Pilot Units (2) (below)

Flocculation Tank, Clarifier and Sludge Storage Tank (below)

Plant at South Site

Aluminum Pilot Plant (above)
Pilot Plant Viewed from Wetland (below)